

Stage Separation CFD Tool Development and Evaluation

9/11/01

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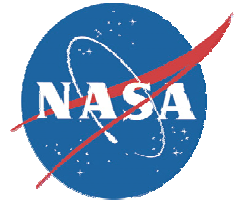
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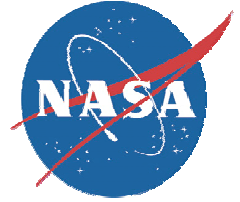
Stage Separation CFD Tool Development and Evaluation



- Background
- Flow Solver Descriptions
- Initial Results
- Lessons Learned
- Future Work



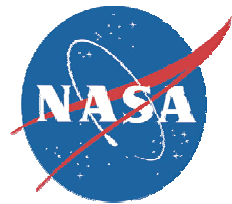
Background



- Second generation reusable launch vehicle (2nd gen. RLV)
 - Space shuttle was the 1st gen. RLV.
 - 2nd gen. RLV concepts - two stages to orbit
 - Risk reduction tasks in FY01 through FY05. Architecture downselect in FY03, full scale development decision in FY06.
- Stage Separation of two lifting/winged bodies - issues
 - Possible recontact after separation, plume impingement, or other unforeseen separation behavior
 - Therefore, aerodynamic and plume data is needed for separation and control system designs.
- Some CFD tools are available and others are being developed. They need to be benchmarked for this type of problem.



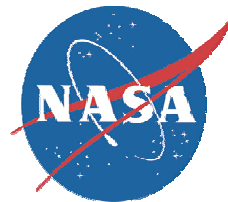
Background (continued)



- Purpose of this task - CFD tool demonstration and validation for second generation RLV stage separation
- Little work has been done in CFD for side by side separation of large lifting/winged bodies
- CFD is needed to expand experimental databases and to cover flow regimes not covered in testing
- Data for multiple configurations is needed to screen 2nd gen. RLV designs in the early design phases - CFD will be faster than test



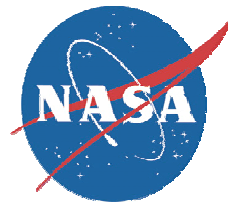
Langley Glide Back Booster Bimese Configuration



- LGBB concept developed by the Vehicle Analysis Branch of Langley Research Center
- Bimese configuration uses OML of two LGBBs belly to belly without canards
- Bimese configuration chosen for aerodynamic tool development because it is a representative 2nd gen. configuration but is not a “real” configuration.



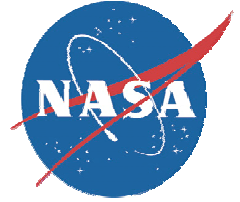
Flow Solver Descriptions



- Cart3D
- Overflow/Overflow-D
- Unic



Cart3D



- Cartesian mesh, Euler solver
- Advantages: Automated meshing, highly parallel, rapid turnaround
- Disadvantages: inviscid, single species, no automatic 6-DOF capability
- Under development: automatic adaption, propulsive flow boundary conditions, viscous capabilities
- Potential 2nd gen. RLV application: early development phases

- Body fitted mesh near body, Cartesian mesh in far field, Chimera, Navier-Stokes solver
- Advantages: Parallel, viscous, moving body, large user base, some grid adaption, multi-species
- Disadvantages: no automatic grid generation, no chemistry
- Under development: Overflow and Overflow-D are being combined to get a code with Overflow's multigrid, grid sequencing, improved turbulence models, and Fortran 90 coding and Overflow-D's moving body 6-DOF, adaptive Cartesian background grid, and MPI capabilities.
- Potential 2nd gen. RLV application: all but the earliest development phases

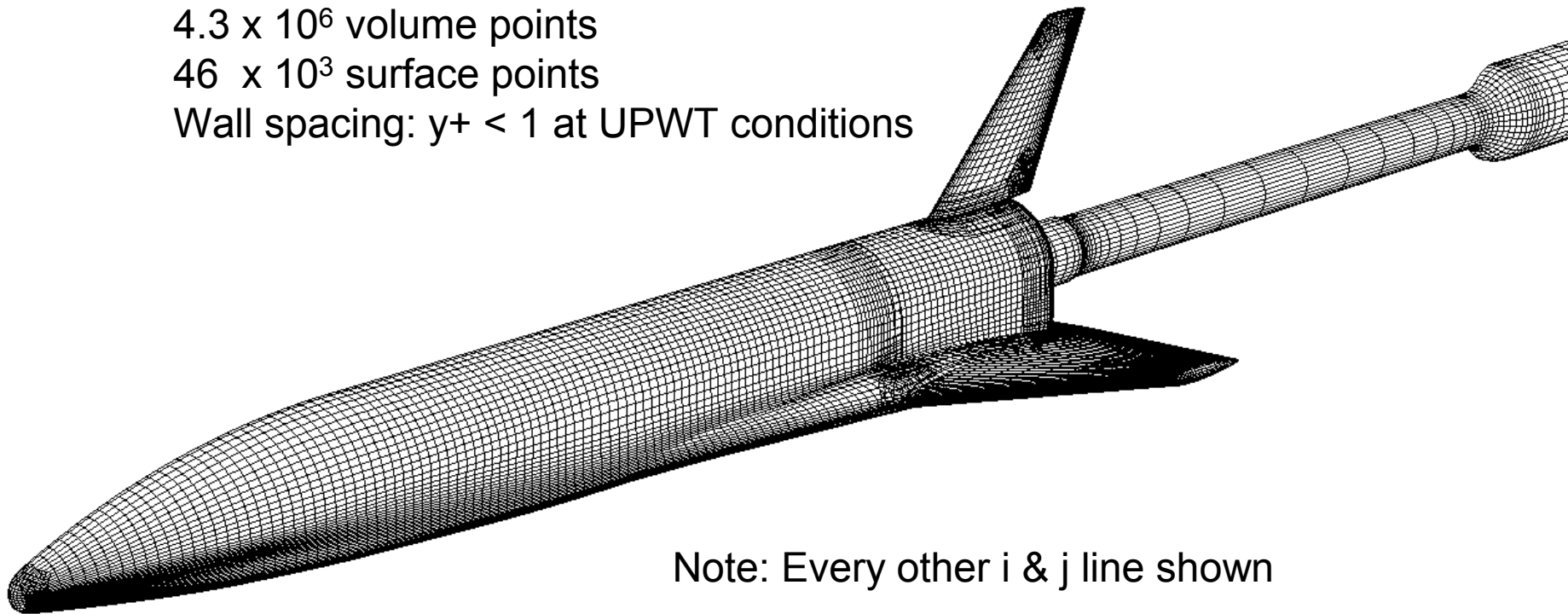
- Unstructured mesh, Navier-Stokes solver
- Advantages: Parallel, viscous, reacting flow chemistry, easy grid generation, mesh adaption, 6-DOF using assumed trajectory
- Disadvantages: code is still under development
- Under development: MPI, multi-body 6-DOF, mesh refinement
- Potential 2nd gen. RLV application: all development phases

Overflow grid system

Generated using Gridgen v13 + CGT

Single LGBB overset grid system

- 17 zones
- 4.3×10^6 volume points
- 46×10^3 surface points
- Wall spacing: $y^+ < 1$ at UPWT conditions



Note: Every other i & j line shown

Overflow solution

Mach 3.0 UPWT

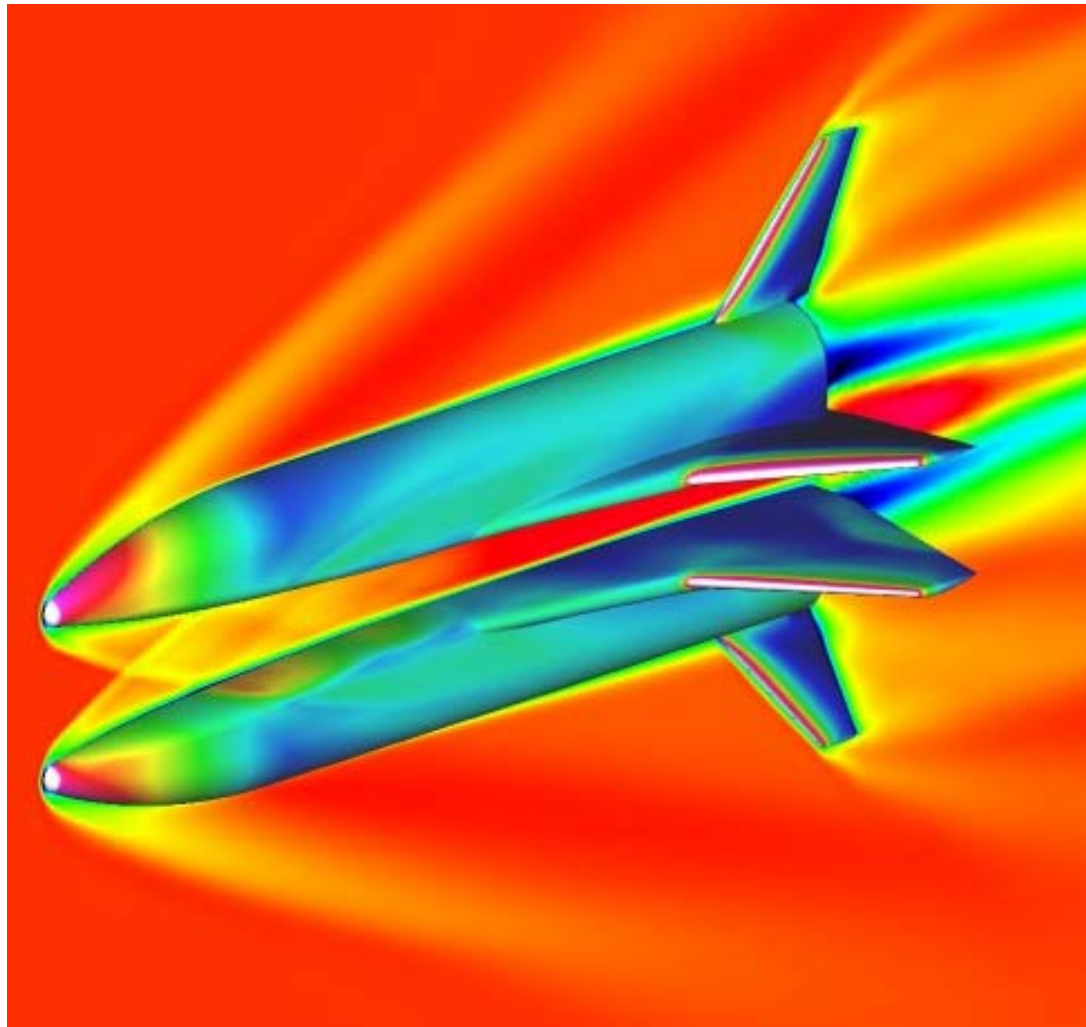
1.75% LGBB

No wind tunnel stings

0.8" separation distance

Cp on vehicle surface

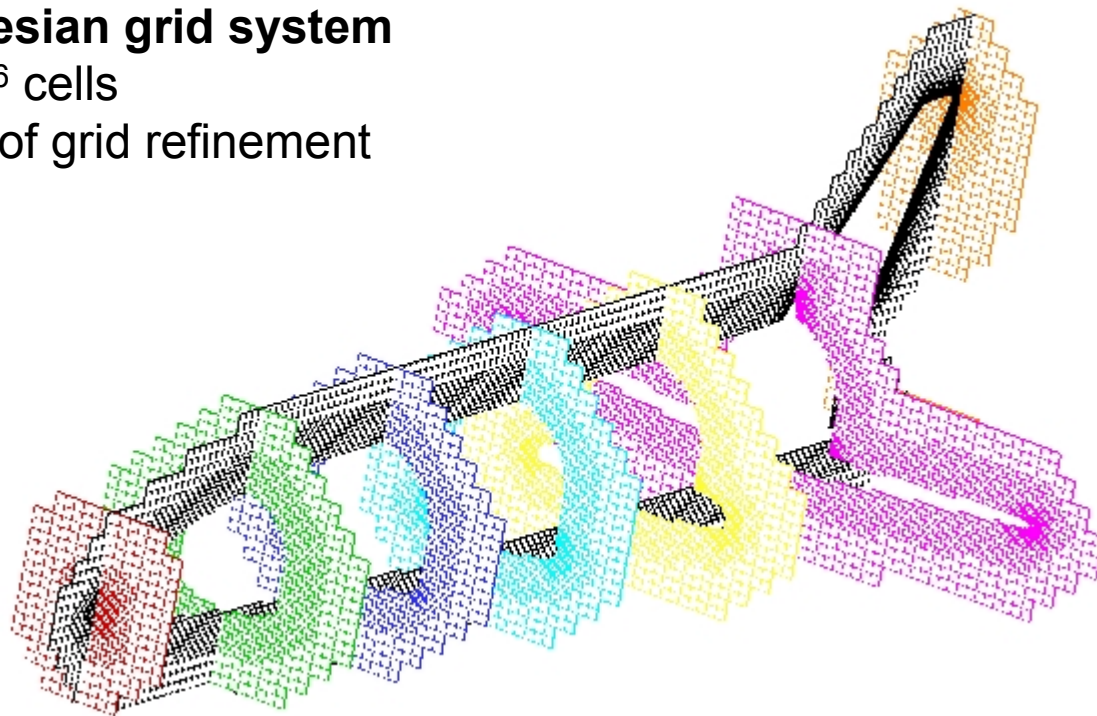
Mach number on $y = 0$ plane



Sample LGBB Cartesian grid system

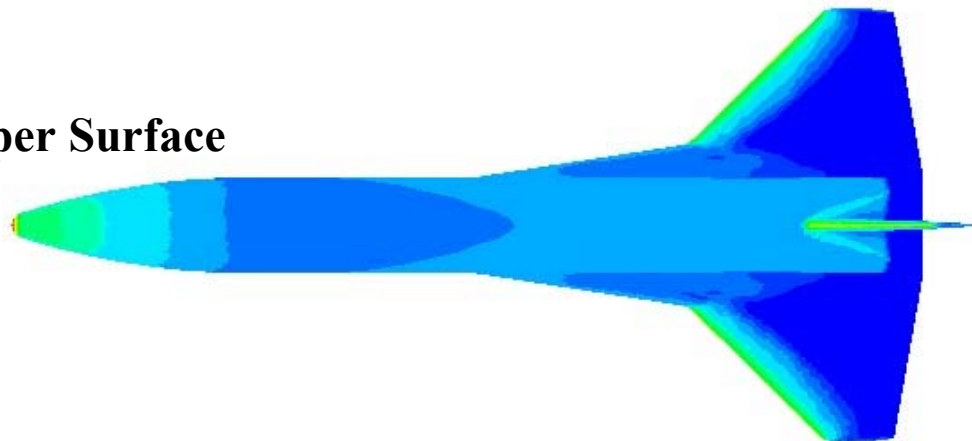
1.1×10^6 cells

7 levels of grid refinement



Note: 3 coarsest levels of refinement not shown

Upper Surface



Mach 3.0

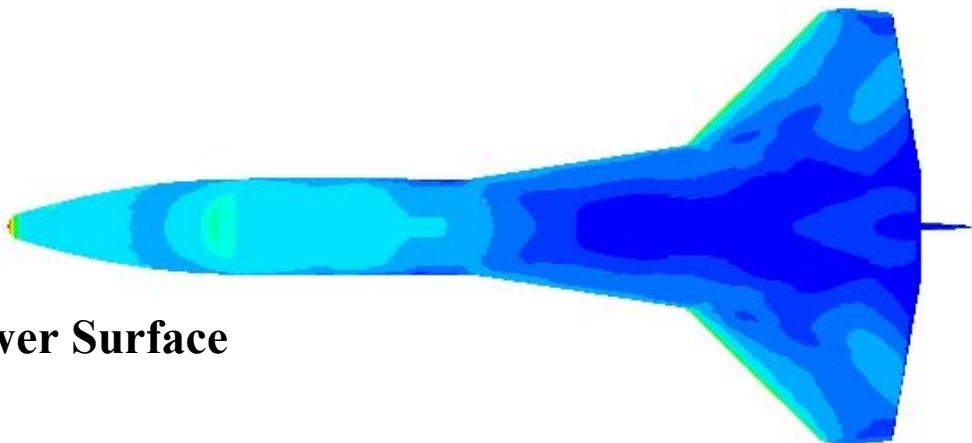
1.75% LGBB

No wind tunnel stings

0.42" separation distance

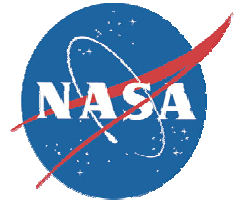
Cp on vehicle surface

Lower Surface





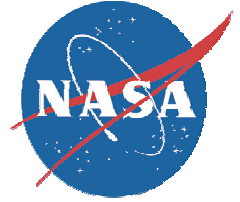
Lessons Learned



- Massively parallel computers and flow solvers have helped bring CFD into the realm of preliminary design tools for vehicle aerodynamics.
- Automated and semi-automated meshing tools in the hands of experienced users have yielded good meshes in a significantly reduced amount of time when compared to work done just a few years ago - Faster, Better, Cheaper.
- Automation of run set-up, convergence checking, and postprocessing is needed. It exists, but is not tightly coupled with the codes investigated in this study.
- Terabytes of storage needed for storage of all files associated with a single CFD aerodynamic database. Question: Is it cheaper to keep restart files or just rerun cases of interest later?



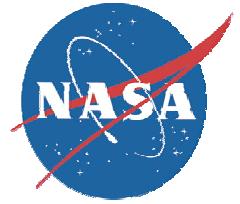
Future Work



- Cart3D
 - Work on new flow solver (add capabilities)
 - Exercise new flow solver and compare results to old flow solver
 - Compute more cases for comparisons
- Overflow
 - Completion of the integration of Overflow and Overflow-D
 - Exercise the combined flow solver
 - Compute more cases for comparisons



Future Work



- Unic
 - Code completion
 - Single and bimese benchmark calculations and comparisons
 - Plume/vehicle interaction simulations
- All
 - Do an apples-to-apples comparison (between CFD codes and between analytical and experimental results)
 - Investigate sting effects
 - Apply codes to downselected configurations
 - Use CFD tools to impact all phases of the 2nd gen. RLV design process